Reflected power does not mean lost power

by KENNETH PARKER, G3PKR*

THE ABOVE TITLE is a quote from *Technical Topics* November 1981, and this article is an attempt to show that the statement is true, even though this would seem to be impossible. How, it might be asked, can the maximum power be going out if some is reflected back to the generator. The explanation which follows has been made as concise as possible to avoid the essential points being lost in unnecessary detail, and involves nothing more than Ohm's Law and some easy-to-use figures.

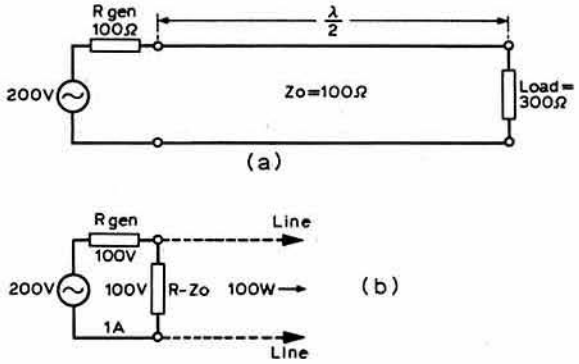

Fig 1. (a) Circuit diagram. (b) Equivalent circuit during first cycle

Take, for example, the line in Fig 1(a) where the mismatch ratio between line and load is 3:1 and the characteristic impedance Zo matches the internal resistance of the generator. Until the reflected energy returns to the input, the generator sees only Zo, so for the purpose of calculation the circuit at this stage can be represented as Fig 1(b), where the line has been replaced by a resistor having the same value as Zo. This shows that the forward voltage and current along the line are 100V and 1A, and the power 100W—the maximum amount that the generator can supply to the line.

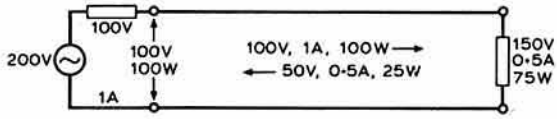

Fig 2. Effect of mismatch

On reaching the load, 50 per cent of the voltage and current (25 per cent of the power) is reflected by the mismatch. The forward and reflected voltages add at the load while the currents subtract, as shown at Fig 2. Taking stock of the conditions at this stage it will be seen that the generator is still supplying 100W to the line, 75 per cent of which is expended in the load, and the rest reflected from it.

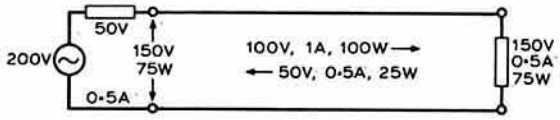

Fig 3. Effect of reflected power on input circuit

By the time the reflected energy arrives back at the input it will have travelled a distance of one wavelength, and the phase of the forward and reflected voltages and currents is such that they will add and subtract as they did at the load. The generator now sees an impedance that has changed from 100 to 300Ω, just as if it were working directly into the load, and adjusts itself accordingly. The conditions existing at this point are as shown in Fig 3. From this it can be seen that although the power supplied to the line is less than it was originally, all of it is now being expended in the load. Note that the forward power is still what it was from the beginning, 100W, but as 25 per cent of it is now being reflected, the net outward flow has dropped to 75W.

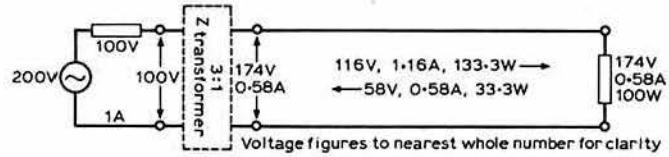

Fig 4. Effect with line and generator matched

The reason for the drop in power supplied to the line, is that its input impedance no longer has the same value as that of the generator. If matching is brought about by means of an impedance transformer, the original output of 100W will again be obtained from the generator and the whole of it will now be delivered to the load, as shown at Fig 4. It will be seen from this that the only effect of mismatching has been to alter the input impedance of the line. Provided that this impedance is made to match that of the generator, as it has to whether the line is mismatched or not, the maximum power will be delivered to the load. Fig 5 shows that the reason why energy can be reflected from the load without reducing the maximum power output, is that the forward power is increased accordingly by the action of mismatching, and in this particular example has risen by one third to 133·3W.

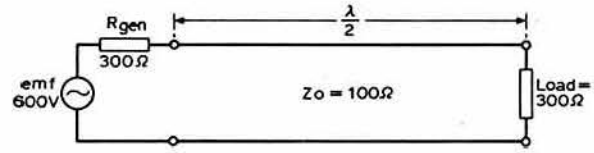

Fig 5. Diagram of modified circuit

If the characteristic impedance of the line had not matched the internal resistance of the generator, some of the reflected power—but not all of it—would have been reflected back to the load. For example, take again the line in Fig 1(a), but this time with the resistance of the generator increased to 300Ω (Fig 5). (To make the figures easy to work with, the emf of the generator has been raised to 600V.)

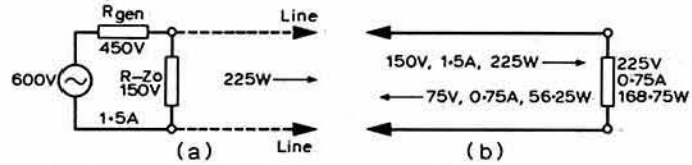

Fig 6. (a) Equivalent of Fig 5 during first cycle. (b) Conditions at load after first half-cycle

At first the generator sees only the impedance of the line (Zo), so at this stage the circuit can be represented as in Fig 6(a), the line being replaced by a resistor equal in value to Zo. From this point on, until the reflected power returns to the input one cycle later (Fig 7(b)), the action will be as already described [Fig 1]. However, there is now an impedance mismatch between the line and generator (3:1 ratio), and 50 per cent of the voltage and current reflected from the load will now be reflected from the generator. The phase of this reflected power in terms of voltage and current, relative to the forward power, is such that they add as shown in Fig 7(a). Comparing this with Fig 6(a) shows the effect of the reflected power on the input circuit. Note that the voltages across the line input and Rgen still add up to that of the emf, as they must do at all times. On reaching the load, 25 per cent of the now increased forward power will be reflected back to the generator (Fig 7(b)).

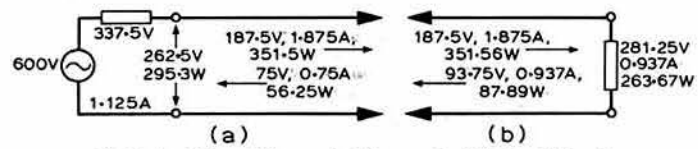

Fig 7. Conditions (a) at end of first cycle; (b) after 1·5 cycles

This process continues with the strength of the forward and reflected power increasing (but at a diminishing rate) with each succeeding cycle, until a state of equilibrium is reached (Fig 8). Equilibrium is reached in the

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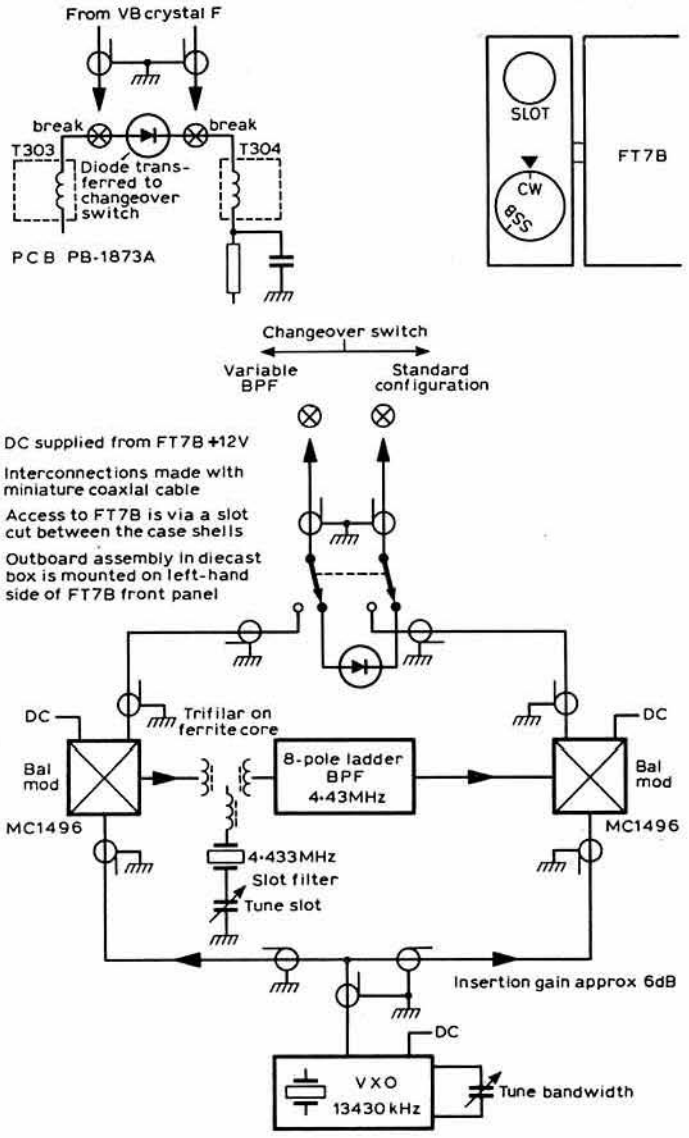

Fig 4. Outline schematic diagram

The tuned circuits are bifilar and trifilar wound coils, where N is the number of turns needed to resonate to the tuned frequency in conjunction with the 60pF preset trimming capacitors. Having determined N, the coil turn numbers are as shown. The value of N depends upon the particular ferrite size and material used (30t 4·3MHz, and15t 9MHz for the author's ferrites). A useful technique to determine the values is to plot N against inductance using a conventional instrument, or a capacitance standard and calibrated grid-dip meter. The required turns for resonance with, say, 40pF, can be determined by calculation. The coils and trimmers are arranged to fill the space above the ics, see Fig 5, but as it is tight the use of a slightly larger box may be preferred.

Power is taken from the FT7B audio amplifier module. Signal input and output leads are miniature coaxial, and all connections are taken via a slot cut between the FT7B top and bottom enclosures where they join. The

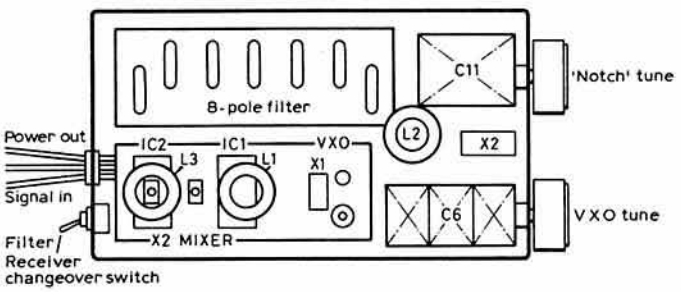

Fig 5. Component layout of the filter unit

Components list

R1, 11	1·2kΩ	**C1,4, 9, 12, 14, 15, 18**	0·1μF ceramic disc, 50V
R2, 10, 18, 19	100Ω	**C2, 3,13**	0·0μF cer disc 50V
R3, 4	560Ω	**C5**	Compression trimmer—part of C6
R5, 13	820Ω		
R6, 15	1kΩ		
R7	22kΩ	**C6**	60pF air-spaced miniature variable
R8, 9, 17	10kΩ		
R12,14	330Ω	**C7, 8**	150pF silver mica or equivalent
R16	120Ω		
R20	220Ω	**C10, 17**	60pF mica compression or equivalent
RV1	1kΩ	**C11**	100pF air-spaced variable
		C16	10μF tantalum 20V
L1, 3	(see text)		
L2	40μH 35G 0·5in ferrite ring	**ICI, 2**	Double balanced mixer-Motorola MC1496
X1	Crystal cut for 13,430kHz	**TR1**	BC107 or equivalent
X2	Colour tv crystal 4·43MHz		

covers may then be removed without disturbing the outboard filter connections. The filter is bolted to the existing recessed holes in the FT7B used for mobile attachment.

Use

In operation it will be found that two settings of the vxo control are most frequently used. One for cw (giving, in conjunction with the FT7B audio filter, a sharp passband centred on 800Hz) and the other, co-incident overlap but with very steep skirts, for ssb (both lsb and usb); these positions may be marked cw and ssb respectively. Variation about these limits will be found useful for difficult signal conditions where, for example, it may be necessary to tune a higher frequency on ssb to remove an annoying "rasp", or vice-versa if the QRM is high frequency.

The notch facility may be left outside the passband for normal use, but will come into its own if, for example, an annoying co-channel carrier needs to be removed (often the case on 3·5MHz). Tuning is quite sharp, and a null of some 30dB is provided. (Leaving the notch capacitor "all plates out" effectively decouples the facility).

Evaluation

Both the modifications described above have been in use for over a year and found to be completely satisfactory. Direct comparison with the author's old (valve) FR100B receiver under various signal conditions definitely gives the edge to the modified FT7B. □

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example being discussed with the generator delivering its maximum power output to the load, but this only happens when the line's input impedance is equal to Rgen. Note that in Fig 8 Zo has been matched to Rgen without the use of an external Z-transformer (see Fig 4).

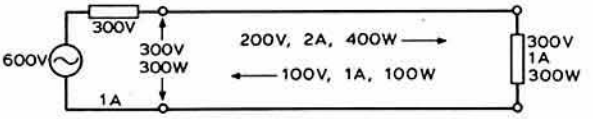

Fig 8. Circuit conditions at maximum power output

The author hopes he has managed to demonstrate in this article that *in a loss-less line* reflected power is not lost or wasted, but is redistributed in the circuit to accommodate the different values of impedance—the redistribution of power producing the ratio of voltage to current required by the various impedances. It is *only* when the transmission line is "lossy" that reflected power contributes additional loss as a result of a mismatched antenna element. □